THE UNIVERSITY OF ALBERTA

THE EFFECT OF CHANGING LEAD LEG, LEG STRENGTH AND ENDURANCE ON STEP TEST PERFORMANCE

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Effect of Changing Lead Leg, Leg Strength and Endurance on Step Test Performance," submitted by Donald John Clark in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

The purpose of this study was to investigate the effect of changing lead leg on step test performance as indicated by changes in the fitness index of the subject. Subsidiary problems were to measure leg extensor strength, leg extensor endurance, and examine their relationship to step test performance. Associated with the strength and endurance tests was the measurement of changes in heart rate during these tests.

Eighteen college males enrolled in freshmen Physical Education classes at the University of Alberta volunteered as subjects for this study. The subjects, in the first two weeks of testing, each completed six step tests involving different sequences of changing lead leg. The third week of testing was utilized for the strength and endurance testing of the leg extensors.

Analysis of test results indicated that changing lead leg does not effect step test performance as indicated by changes in the fitness index of the subject. A significant relationship was found between leg extensor endurance and step test performance, while a nonsignificant relationship was found between leg extensor strength and step test performance. Significant differences were found between the heart changes during the maximal strength and endurance tests, however both tests did result in heart rate changes great enough to elicit a training effect.

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CHAPTER 1

STATEMENT OF THE PROBLEM

Introduction

Step tests (8, 56, 64) and adaptations of step tests (4, 10, 12, 32, 35, 39, 43, 60, 63, 66) have provided Physical Educators with a test of physical fitness or physical efficiency for a number of years. The step test does not require sophisticated equipment and has been widely used in field situations because of its relative simplicity of administration and interpretation.

Physical Educators often turn to fitness tests requiring more expensive and specialized equipment rather than use the step test under the pretense of more accurate results. Tests (3, 15, 58) have shown that fitness levels as determined by step test methods correlate significantly with physical fitness levels defined following treadmill and ergocycle tests. Hemingway (36) has suggested step tests may yield more reliable results than treadmill or ergocycle tests in field situations because there is little anxiety associated with the step test and the stepping exercise promotes venous return which may be partially occluded in the sitting position required during ergocycle tests. Shephard (58) suggests personal and physiological considerations are often

outweighed by practical problems when choosing experiment apparatus. A treadmill is bulky, expensive, noisy and requires a source of electrical power. A bicycle is less bulky, but the more accurate models are expensive and often require electrical power for the braking system or pacing device. If valid measurements are to be made on bicycles frequent and careful calibration is necessary. Step tests are simple, need neither electricity nor elaborate calibration, and are readily made at little cost.

However, while the step test has these practical and physiological advantages, questions have been raised with regard to the effect of bench height, cadence, knee angle, anthropometric measures, leg strength, leg endurance and the amount of time each leg is used as a lead leg during the step test.

The Problem

The purpose of this study is to investigate the effect of changing lead leg on step test performance as indicated by changes in the fitness index.

Subsidiary Problems

Associated with this study are the following subsidiary problems:

1. The measurement of leg extensor strength from a standing position similar to that of stepping up onto the bench and its relation to step test performance.

2. The measurement of leg extensor endurance from positions similar to that of stepping up onto the bench and its relation to

step test performance.

3. The measurement of the changes in heart rate during maximal strength and endurance tests of the leg extensors.

Hypothesis

The null hypothesis for the main problem will be that there is no difference in the fitness index when the lead leg is changed at selected intervals.

The null hypotheses for the subsidiary problems will be:

1. There is no relationship between leg strength and step test performance.

2. There is no relationship between leg endurance and step test performance.

3. There is no difference in the changes in heart rate during maximal strength and endurance tests.

Justification

A problem that has been associated with step tests is the subjects complaining of muscle soreness in the legs during the test and muscle stiffness in the legs following the test. More specifically subjects report that the lead leg they use becomes fatigued and this causes them to discontinue the test. If an optimal time pattern for changing lead leg can be established than the effects of local fatigue will be equally spread between both legs and some of the problems of muscle soreness and stiffness relieved. The nature of the relationships between leg extensor strength, leg extensor endurance and step test performance will indicate the role of local strength and endurance in step test

performance.

Delimitations

The delimitations of the study are:

1. The study is concerned with the measurement of performance of individuals employing a specific step test.

2. The study is concerned with the measurement of strength and endurance variables with specific techniques and in specific positions.

3. The study is concerned with cardiac response during the specific step, strength and endurance tests employed in the study.

Limitations

The limitations of the study are:

1. The number of subjects selected (18) and the method of selection.

2. The methods and techniques of measurement.

3. The statistical methods and procedures used to investigate the data.

4. The experimental error of the investigator.

Definition of Terms

Lead Leg - the leg the individual places on the bench first when the step up is initiated.

Muscular Strength - a measure of the force an individual can exert in a single muscle contraction.

Muscular Endurance - the ability of a muscle to persist

in a movement ie. continue to do work with a definite rate of contraction.

Resting Heart Rate - the heart rate of an individual following a three minute rest in a sitting position.

Maximum Heart Rate - the heart rate immediately following the cessation of the strength and endurance measurements. This measure is not necessarily the physiological maximum of the individual.

CHAPTER 11

REVIEW OF LITERATURE

Step Test Studies

Brouha (9) suggests that it is easier for the subject to use the same lead leg throughout the step test and not try to alternate legs. He further states the subject can alternate, "2 or 3 times during the test if one leg gets tired", giving no physiological or statistical basis for this statement.

Bookwalter (8) administered the Brouha Step Test to 1,269 students at Indiana University and studied test correlation with age, height, weight, 100 yard pick-aback, 300 yard dash and seven Army Test events (pushups, burpees, situps, 100 yard pick-aback, squat jumps, pullups and 300 yard dash). As a result of the correlations Bookwalter (8) states:

1. The Brouha Step Test is nonsignificantly related statistically to all factors.
2. Of all the items correlated there is slightly more relationship (inversely) between the Brouha Step Test and height.
3. There appears to be a low negative relationship between the Brouha Step Test and age, height and 100 yard pick-aback.

Keen and Sloan (45) after applying the Harvard Step Test

to 75 young men found no significant correlation with stature, weight, length of leg and bi-iliac diameter. The inverse correlation with resting pulse rate was highly significant.

Seltzer (56) concluded following the testing of 800 cadets and college students on the Harvard Step Test that there was not a significant relationship between the Fitness Index and stature, weight, lower extremity length and lower leg length.

Elbel and Green (26) used a standardized cadence of 24 steps per minute with steps of 12, 14, 16, 18, 20 inches in height during exercise periods of 30 and 60 seconds duration. They reported that the pulse in healthly male subjects taken one minute after exercise returned to approximately the pre-exercise level, regardless of the height of the bench or whether the exercise was 30 or 60 seconds duration.

Miller and Elbel (50) used a 16 inch bench and cadences of 18, 24, 30, 36 and 42 steps per minute for a one minute test. They concluded that the pulse rate immediately following exercise increased on the average 9.15 beats per minute for each increase of 6 steps per minute.

Cullumbine, et al (16, 17, 18) investigated the relationship between several anthropometric measures and three Step Tests. The Step Tests used were the Harvard Step Test, an Endurance Step Test (20 inch bench, 45 steps per minute for as long as possible) and an Exhaustion Step Test (20 inch bench, 30 steps per minute for as long as possible). The conclusions following testing were:

1. The Harvard Step Test Index correlated significantly

with bi-iliac diameter/height, chest circumference/height, the bi-iliac diameter and bi-zygomatic diameter.

2. The Exhaustion Step Test Index correlated significantly with weight, height and leg length.

Hardy, et al (35) reported following experiments on several hundred young men and women that there were no differences in Step Test scores for short and tall subjects.

Gallagher and Brouha (33) suggested careful adjustment of bench height in relation to the size of the individual was not necessary as the work load is determined more by the individuals mass which must be lifted each step.

Elbel, et al (27) reported a significant relationship between Harvard Step Test Scores and weight, height and leg length (greater trochanter to floor).

Ariel (1) administered the Harvard Step Test to 33 college males at four different knee joint angles. Significant differences were found in the Fitness Index scores for the four different angles.

Astrand and Ryhming (3) have found the step test maximal oxygen consumption to be closely related to maximum oxygen consumption as determined by treadmill or ergocycle tests.

Ronkin (53) found the coefficient of correlation between the ten minute recovery pulse count and the 60-90 second recovery pulse count for the Harvard Step Test to be .92 when he investigated the effect of different recovery pulse counts on the fitness index.

Karpovich (42) found the test-retest reliability of the rapid form score for the Harvard Step Test to be .73 following tests on 187 men.

Day (21) following a statistical investigation of the Ryhming Step Test has suggested improved performance in Step Test "test-retest" situations may be attributed to subject familiarity with the test and testing situation during subsequent administrations. Day suggests anxiety may result from the individuals concern for their ability to be able to complete the step test during the first test administration, thus the added importance of adequate pre-test orientation.

Leg Extensor Strength Test Studies

Buck (11) reported that the most reliable measure of leg lift strength to be an experimental method developed for his study. The method employed used a leg dynamometer, experimental belt and a vertical backboard. The experimental belt eliminated the use of the hands and lunging was prevented by the vertical board.

Linford (46) following leg strength tests at various angles reported maximum strength to be between knee angles of 135-160 degrees at moment of maximum contraction. Linford and Rarich (47) reported when the semi erect method of testing is used to measure static leg strength the highest strength scores are obtained when the knee angle is between 135 and 164 degrees. The variations in knee angle between 135 and 164 degrees did not however produce significant differences in the recorded leg strength score.

Danielson (20) after studying concentric, eccentric and isometric strength found the optimum angle for leg extensor strength to be 150 degrees during concentric and isometric tests.

Basmajian (5: 223) following electromyography studies of the leg extensors reported that muscular activity was greatest as the knee angle extended from 135 degrees to 180 degrees.

Berger (7) found the optimal angle for inverted leg press (knee extension) to be 140 degrees. The average strength reported for the eighteen college males tested was 456.94 pounds for each leg.

Leg Extensor Endurance Test Studies

Stothart (62) has suggested that endurance measurements generally include tests in activities in which the individual performs until exhaustion. The endurance test of the leg extensors used in this study was a measure of the individuals ability to hold a weight at a given angle for as long as possible. Stothart concluded that endurance is task specific and that endurance as measured in one activity may not correlate with endurance as measured in a second.

Fleishman (31) found endurance to be specific to various skeletal muscle groups including the leg extensors. He suggested stamina to be a measure of cardiovascular endurance measurable by prolonged exertions of the whole body.

Willgoose (67) and Clarke (13) suggest several endurance tests and motor fitness tests for the leg extensors. These tests include: squats, squat jumps, shuttle runs, vertical jumps and

endurance runs.

Endurance tests appear to be based on several principles. One type of endurance test (48) is based on the individuals ability to exert force equal to a percentage of the maximal strength exerted and the holding of this force in a set position for as long as possible. A second type of endurance test (49, 65) tests the ability of the individual to maintain maximum exertion for a set amount of time. A third type (6, 14, 25, 38) requires the individual to repeat a set task to a time limit or until fatigue occurs.

Strength Endurance Relationships

The relationship between strength and endurance in most studies appears to depend on the method of determining either the strength or endurance measure.

Fait (28) stated that since there is a relationship between muscular strength and muscular endurance, muscular strength could be determined from the endurance measure.

Fleishman (31) concludes that there are three main 'strength' factors, static strength, explosive strength and dynamic strength. Dynamic strength is the ability to exert muscular force and resist the onset of fatigue.

Jokl (40: 170) has expressed the view that there is no relationship between strength and endurance and supports his argument as follows:

> A hypertrophic muscle is well equipped to meet situations of the kind which caused its structural adaptation, that is

> to say, situations demanding a display of strength. However, a muscle thus adapted is not able, by virtue of this anatomical adjustment, to deal with other tasks which it may encounter in the course of physical activities. For example, endurance, the ability to work efficiently for an extended period, taxes different properties. Hypertrophy of muscle may even constitute a handicap in the performance of muscular tasks demanding endurance. The opposite statement also holds good, as is borne out by the limited strength of the child's muscles, though children possess as a rule, great powers of endurance. The principal adaptive reaction of tissues to physical performances demanding endurance is increased capillarization, which has been demonstrated in the heart, brain, anterior horns of the spinal cord and skeletal musculature.

Jokl (40: 175) further argues:

> The two forms of adaptation of muscle, hypertrophy and capillarization, occur specifically as a result of two distinctly different physiological stimuli...frequent display of strength evokes hypertrophy whereas frequent sustained effort increases capillarization.

Pierson and Rasch (52) found following a study of strength training there was a negative effect on endurance.

Start and Graham (61) found a highly significant ($r=.75$) relationship between isometric strength and absolute isometric endurance, but a non significant relationship between isometric strength and relative isometric endurance.

Tuttle, Janney and Salzano (65) after testing back and leg strength and endurance concluded that individuals with greater maximum strength have a greater absolute strength endurance, but these individuals can maintain a smaller proportion of their maximum strength for the same period of time as those with less initial strength.

Elbel (25) after testing 515 potential pilots, on a dynamomometer utilizing a sitting position found significant correlations (.35, .26, .32) between leg strength and endurance.

Irish (38) following his study of the elbow flexor muscles reported a negative correlation of -.38 between elbow flexion strength and elbow flexion endurance. The endurance test was relative to the maximal strength.

McGlynn investigating the relationship of maximum strength and endurance found correlations of .72 to .80. The endurance test score was the average of 10-10 second recordings of maximum exertion of forearm flexors.

Clarke and Stull (14) reported after studying the effects of endurance training found significant increases in strength, but did not find any change in the fatigue rate following training. They concluded that this type of training would thus enhance muscular strength and absolute endurance, but does not increase relative endurance.

Berger (6) tested 61 college males on a bench press lift and reported the coefficient of correlation between maximum dynamic strength and relative dynamic endurance to be -.40. He further concluded that individuals of high dynamic strength may have less relative muscular endurance with loads of 50 percent of maximum dynamic strength than weaker individuals. Martens and Sharkey (48) utilizing a test of elbow flexors found a similar correlation -.42 between static strength and relative endurance.

Strength per Unit Body Weight

Cureton (19: 370) states:

> A significant concept is strength per pound of body weight, commonly written strength/weight. A very small man cannot

> reasonably be expected to have as much strength as a large man but, proportionately, a small man should have as much strength as a large man. A small man does not need as much strength to lift or propel his body as a large man. Strength per pound body weight is a way of emphasizing the strength according to the needs.

Cureton found in studies on 106 Illinois freshmen high correlations between strength/weight, strength, and motor fitness scores. Positive, but insignificant correlations were found between strength/weight, cardiovascular tests and respiratory measurements.

Asmussen (2: 33) after studying hip-knee muscles in relation to height has reported a significant logarithmic relationship between isometric strength and body height and weight (size).

Elbel (25) found significant correlations between body weight and strength and non significant correlations between body weight and endurance during a study of 515 potential pilots. He states:

> Since there is a significant relationship between body weight and leg strength, the reduction in weight would materially reduce leg strength. However, the roduction of weight would not materially reduce leg endurance.

Changes in Heart Rate During Different Types of Exercise

Morehouse and Miller (51: 103) discussing heart rate changes during exercise state: "the type of exercise influences the amount of increase in heart rate". They report greatest acceleration in exercises of speed and smallest acceleration in exercises of strength.

de Vries (22: 74) suggests that in maximal static exercises only slight increases in heart rate are observed while in vigorous

alternating contractions a large increase in heart rate occurs. He explains the differences on these two bases:

1. Venous return may be decreased in the straining exercise due to increased intrathoracic pressure, and it may be increased in dynamic exercise due to the pumping action of the muscles.
2. The heart rate is proportional to the workload per unit of time, and slow, straining exercises seldom create a workload sufficient to bring about large responses in heart rate.

Shephard (58: 170) suggests there may be harmful effects during sustained isometric exercise because of the stress that the increased arterial pressure places upon the walls of the blood vessels and the resulting large increase in the work of the heart. He suggests in the case of athletic training, however, studies have shown that a 70 percent contraction for six seconds provides for strength development, without a substantial rise of blood pressure.

Shvartz (59) following a study involving 45 second exercise periods for isotonic and isometric exercises (military press) and the resultant effect on heart rate made the following conclusions:

1. Isometric and isotonic exercise performed with one half of maximum load can stimulate heart rate equally.

2. Increasing the load in isometric contraction results in a proportional increase in heart rate.

3. Maximum tension developed isometrically results in a near twofold increase in heart rate above resting levels.

Changes in Heart Rate Necessary to Elicit a Training Effect

Hollmann and Venrath (37) demonstrated that half an hours training four times a week at a heart rate of 115-125 beats per minute leads to a lower heart rate at rest and during submaximal exercise. Further study indicated that five weeks of additional training at a heart rate of 170-180 beats per minute resulted in both maximal oxygen uptake and heart volume increases.

Studies directed toward discovering the minimum heart rate necessary to stimulate cardiovascular improvement by Karvonen, Kentala and Mustala (44) resulted in the contention that to improve the exercise tolerance of the cardiovascular system the heart rate during an exercise bout must be increased at least 60 percent of the difference between the resting and maximal rate. They further reported the training threshold necessary to elicit an increased tolerance to exercise to be approximately 150 beats per minute.

Durnin, Brockway and Whitcher (23) observed that walking which elicited heart rates of 120-130 beats per minute resulted in significant changes in heart rate response to a set work task.

Roskamm (54) found that training at a heart rate of 70 percent of the difference between the heart rate at rest and that during maximum effort was effective in significantly improving

physical work capacity.

Sharkey and Holleman (57) presented data which indicated the need for a heart rate above 150 beats per minute during exercise before a training effect is elicited.

Faria (29) reports that there may be a threshold for a training effect on the cardiovascular system, reflected by a lower heart rate for a given amount of work. Faria trained individuals to heart rates of 120-130, 140-150 and 160-170 beats per minute. The analysis of his data indicated that training to 120-130 beats per minute did not significantly improve work performance but that the 140-150 and 160-170 beats per minute groups did have significantly improved work performance. The differences between the 140-150 and 160-170 beats per minute groups were not statistically significant. The following conclusions were made:

1. A submaximal stimulus might elicit optimal training of the cardiovascular system.

2. The terminal working heart rate is a key factor when considering a training stimulus necessary to elicit changes in physical work capacity.

3. Short exercise bouts five times per week for four weeks will significantly increase the physical work capacity of untrained young men.

CHAPTER 111

METHODS AND PROCEDURES

Subjects

Eighteen males enrolled at the University of Alberta in the freshman Physical Education program volunteered as subjects for the study. The subjects were not involved in any specific activity training program at the time of testing.

Experimental Design

The duration of the study was four consecutive weeks. The first week was comprised of two orientation sessions. The first session was used to give the subjects an overview of the testing to be done and practice in changing lead leg without losing the metronome cadence. The second session was used to demonstrate the equipment and techniques to be employed in the strength and endurance measurements. In the second and third week the step test treatments were administered on alternate days. On the first test day of the fourth week the strength measurements were taken. The second and third testing days of the fourth week were used for the endurance measures.

A daily testing schedule was arranged for the subjects. This schedule made it possible to test each subject at approximately the same time each session.

Step Test Treatments

The step test used in this study was of four minutes duration. The height of the bench used was eighteen inches. A metronome cadence of 120 beats per minute was used. The cadence was determined by the use of a Frantz Electric Metronome Model LM-FB-4. This allows for 30 complete steps per minute.

This specific step test was used since the subjects were not trained athletes and the experimental design necessitated that each subject complete the four minute test. The six step test treatments were:

1. Subjects own choice of lead leg - can start with either leg and change when desired.

2. Subject uses only left leg as lead leg.

3. Subject uses only right leg as lead leg.

4. Subject changes lead leg after two minutes.

5. Subject changes lead leg every minute.

6. Subject changes lead leg every thirty seconds.

In order to ascertain full extension of the knee joint on each step during the test two poles were placed six inches in from the edge of the bench and a one inch wide elastic band was placed one inch below the standing height of the individual as measured in their gym shoes. The subjects were asked to touch the elastic with their head on each step up.

The pulse count was determined by the use of a Sanborn 500 Viso-Cardiette electrocardiograph. Three surface electrodes, one immediately below each nipple and one at the base of the right

scapula, were strapped to the individual. The electrodes were covered with Redux electrode paste to increase the conductivity of the skin. The electrodes were connected via leads to the electrocardiograph. The electrocardiograph was turned on 50 seconds post exercise and the tracing marked at 60 seconds post exercise and again at 90 seconds post exercise. The electrocardiograph tracings were collected for each individual and the 30 second pulse count was determined from the tracing.

Step test performance was based on the Fitness Index as calculated by the rapid form of the Harvard Step Test Index of Fitness (41: 285):

$$\frac{\text{Duration of Exercise (Seconds)} \times 100}{5.5 \times \text{Pulse Count (30 seconds)}}$$

The procedure for each testing session was as follows:

1. Check master sheet for step test treatment to be done by subject.

2. Measure standing height in gym shoes and adjust elastic band above bench to one inch below standing height. (Height measured only before first test session.)

3. Attach electrodes and leads for electrocardiograph.

4. Start Metronome.

5. Subject faces bench and begins step test, making certain that subject is extending knees fully to get a touch sensation from the elastic band each step up.

6. Subject completes four minute step test and immediately sits down on bench to rest.

7. Heart rate is recorded on electrocardiograph from

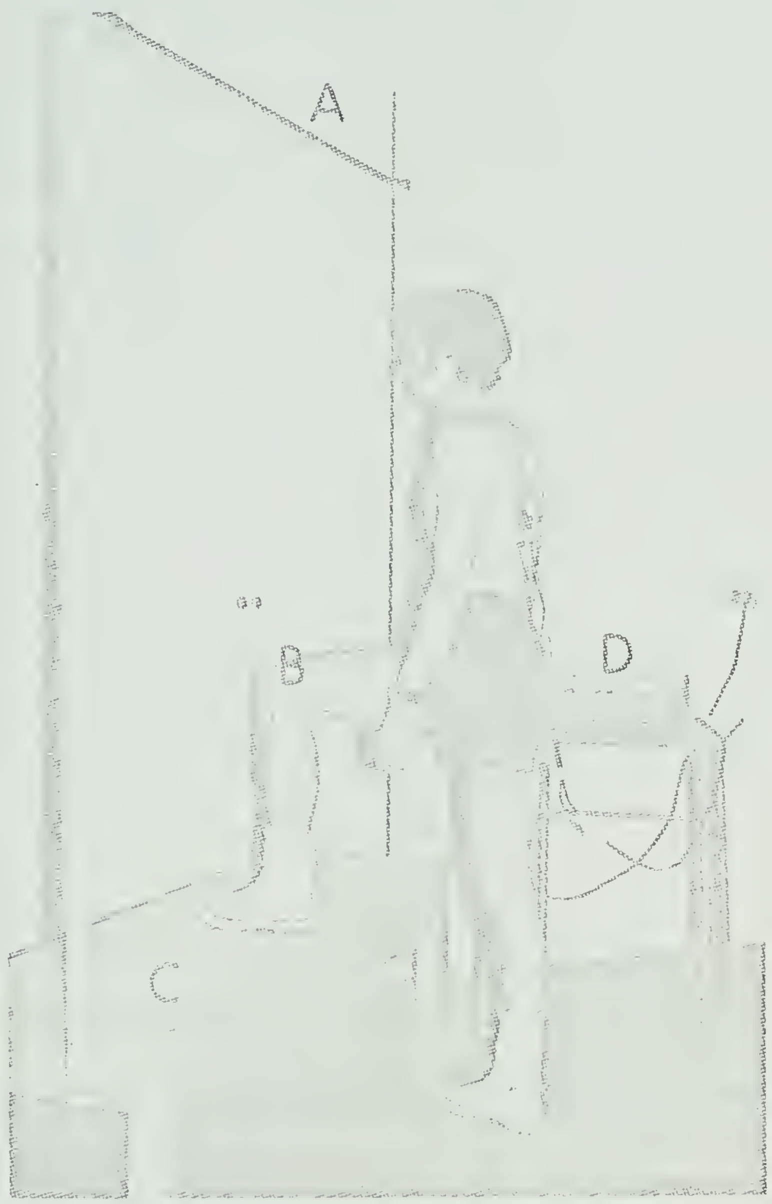

FIGURE 1

APPARATUS FOR THE STEP TEST

AND THE ENDURANCE TEST

A. Elastic Belt For Touch Sensation

B. 90 Degree Knee Angle (Endurance Test)

C. Adjustable Bench

D. Electrocardiograph With Leads And Electrodes

60-90 seconds post exercise.

Before starting the treatment which allowed for the subjects own choice of lead leg, the subjects were asked to indicate which leg they considered to be their dominant leg on the basis of performance. The subjects were asked to use this dominant leg as their lead leg to start this treatment. The number of times the lead leg is changed and the amount of time each leg is used is recorded. The subjects were asked to indicate a change of lead leg by saying "change", this enables the investigator to stop or start the stopwatch indicating the time each leg was used. So as not to influence the subject during this treatment no time intervals were called out during the step test.

Leg Extensor Strength

The leg extensor strength was measured using the modified electro leg dynamometer. The construction of the dynamometer allowed the following:

1. A sliding back support which can be adjusted horizontally such that the force applied to the load cell is in an absolute vertical direction for each individual.

2. Upper body stabilization through the use of shoulder straps and yokes.

3. Effective adjustment of the knee angle by the lengthening or shortening of the cable.

The extensor strength was determined by attaching a 3000 pound capacity load cell (BLH Electronics Model U3G1) to the cable

and to a belt specially constructed for this purpose. Signals from the load cell were received and amplified by a Beckman RS Dynagraph (9853 Strain Guage). The amplified signal was recorded on a Sargent SRG Recorder. The Sargent Recorder was calibrated electronically and mechanically from 0-1000 pounds. The calibration was such that each half inch deflection from 0 was equal to 50 pounds on the tracing output. The measure expressed in pounds force exerted for each leg.

The procedure for the test session was as follows:

1. Subjects weight recorded (shoes and shirt removed).

2. Attach electrodes and leads for electrocardiograph.

3. Reference points marked on leg for knee angle.

4. Cube drawn to determine left or right leg tested first.

5. Subject sits down for 3 minute rest.

6. Resting heart rate recorded.

7. Belt and load cell attached for strength test (foam pad inserted for additional protection).

8. Subject stands on dynamometer, sliding backboard and shoulder straps and yokes attached.

9. Subject places instep of foot of leg to be tested as near as possible without touching to the dynamometer cable.

10. Cable shortened until knee angle 135° against slight tension.

11. On "lift" command subject contracts extensors of leg being tested and lifts the other foot off the surface of the dynamometer platform, subjects hands remaining by his side.. The duration of the contraction being approximately three seconds.

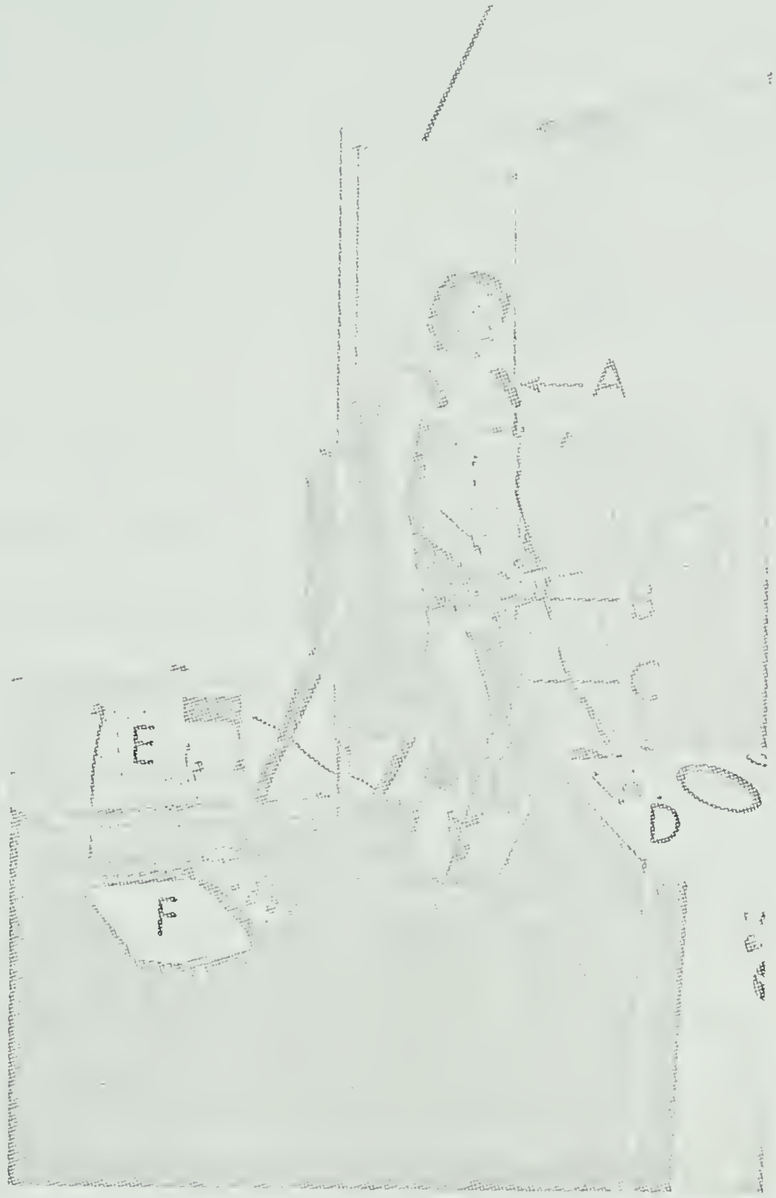

FIGURE 2

APPARATUS FOR THE STRENGTH TEST

A. Adjustable Sliding Backboard With Shoulder Straps And Yokes

B. Safety Belt

C. Load Cell

D. Modified Electro Dynamometer

E. Beckman RS Dynagraph

F. Sargent Recorder

12. A ten second rest is allowed before testing the opposite leg. Each leg is tested three times.

13. The maximum heart rate is recorded immediately following the final (sixth) contraction.

The knee angle was determined by using three reference points:

1. The greater trochanter of the femur which was determined by palpation below the iliac crest.

2. The lateral condyle of the femur.

3. The lateral malleolus of the fibula.

These points were marked using a Micropoint Wik-Stik pen.

The placement of the electrodes for the strength test was laterally on the ribs and at the base of the sternum. The minute heart rate was determined using the "distance for three beats" method as determined in the CAHPER PWC 170 test.

The average strength in pounds per leg was determined and divided by body weight. This measure was then expressed in terms of pounds strength per leg per pound body weight to give strength per unit body weight. The body weight was determined by use of Detecto-Medic scales.

Leg Extensor Endurance

The leg extensor endurance was measured using a repeated single leg step up onto the bench. The subject placed the leg to be tested on the bench with the heel two inches in from the edge of the bench. The height of the bench was then adjusted such that the angle of the knee joint is 90 degrees when a line drawn from the lateral condyle of the femur to the distal anterior surface of

the fibula is perpendicular to the bench and a line from the greater trochanter of the femur to the lateral condyle of the femur is parallel to the surface of the bench. This adjustment of the knee angle allows every subject to have equal angular mechanical advantage in the endurance test. The subject steps up onto the bench fully extending the knee of the leg being tested every second and down from the bench every second with the opposite leg. The complete cycle being two seconds duration. The cadence was determined using the Frantz electric metronome set at 60 beats per minute.

The procedure for each test session was as follows:

1. Subjects body weight and standing height recorded (shoes and shirt removed).

2. Cube drawn to determine leg to be tested.

3. Length of upper leg measured.

4. Length of lower leg measured.

5. Bench height selected such that knee angle 90°.

6. Attach electrodes and leads for electrocardiograph.

7. Subject sits down for three minute rest.

8. Resting heart rate recorded.

9. Subject faces bench and places foot of leg to be tested on the bench.

10. Subject begins test and continues until exhaustion or until one step behind the cadence.

11. Maximum heart rate recorded immediately following the termination of the test.

The reference points for the measurement of upper and lower leg lengths were:

1. The distance from greater trochanter of the femur to the lateral condyle of the femur was recorded as upper leg length.

2. The distance from the lateral condyle through the lateral malleolus of the fibula to the bench was recorded as lower leg length.

The endurance of the leg extensors was then expressed in terms of work (foot-pounds) done by each leg. The method of calculation being:

$$\frac{\text{Number of Repetitions x Length of Upper Leg x Body Weight}}{12}$$

Statistical Treatment and Analysis

A six by six Latin Square design was used in the study. The Latin Square to be used was randomly selected (24: 176). The step test treatments were randomized such that each treatment occurs only once in each row and column. The random treatment assignment was as follows:

Treatment A - subject uses only left leg as lead leg

Treatment B - subject changes lead leg after two minutes

Treatment C - subject changes lead leg every thirty seconds

Treatment D - subject uses only right leg as lead leg

Treatment E - subject changes lead leg every minute

Treatment F - subjects own choice of lead leg

Three subjects were randomly assigned to each order of presentation. The design provided tests for the significance of: the order

of treatment presentation effect, the day (training or carryover) effect, and the treatment (changing lead leg) effect. The analysis of variance was done on the Commodore AL-1000 Desk Top Computor. Duncan's Multiple Range Test was used to test for significant differences between means of those effects which were significant in the analysis of variance. All tests of significance in the study were done at the .05 level of confidence.

A correlation matrix was computed for the test variables using the Pearson product - moment correlation coefficient (30: 109), the print out included the means, standard deviations and intercorrelation matrix.

Test-Retest reliability coefficients for the strength measures were determined from the correlation matrix.

A "t-test" was used to test for significant differences in heart rate for resting, exercise and mean difference during the strength and endurance tests.

All data was tested for skewness by the application of a program which gave the percentile rank of each score, the mean and standard deviation, along with the direction of the skewness, the standard error of skewness and a "t-test" score for significance of skew.

CHAPTER IV

RESULTS AND DISCUSSION

Results

The analysis of the data is sectioned for the Step, Endurance and Strength tests, followed by the relationships between selected variables from the three tests.

Step Tests

The analysis of the Step test data is presented in the following order: means, standard deviations and range of Fitness Indices; analysis of variance of Fitness Indices; test for significant differences between means of significant effects; Treatment F means, standard deviations and ranges for individual leg times and number of changes of lead leg; the test day correlations and the test treatment correlations.

The means, standard deviations, and ranges of each of the Step Test Fitness Indices are presented in Table 1.

TABLE 1

FITNESS INDEX MEANS, STANDARD DEVIATIONS AND RANGES

Treatment	Mean	S.D.	Range
A	73.84	19.50	55.26 - 136.36
B	74.28	17.99	57.42 - 121.21
C	74.96	18.81	54.55 - 121.21
D	71.78	13.08	56.67 - 106.43
E	72.49	12.98	58.97 - 109.09
F	71.59	13.82	56.67 - 114.83

The "t-test" of the skewness of the treatment scores did not yield any significant values.

The analysis of variance of the Step Test Fitness Indices is presented in Table 11.

TABLE 11

ANALYSIS OF VARIANCE - SUMMARY

FITNESS INDICES

Source	Sums of Squares	df	Mean Square	F
Order	6,592.90	5	1,318.58	.92
Error (a)*	17,061.02	12	1,421.75	
Days	688.97	5	137.79	4.34
Treatments	176.57	5	35.31	1.11
Error(b)**	2,540.96	80	31.76	
Total	27,060.92	107		

* Error(a) is the pooled sum of squares between subjects tested with the same order.

** Error(b) is the sum of squares for the Latin Square error sum of squares and the pooled subject X period sum of squares.

$F_{.05\ df\ 5,12} = 4.68$

$F_{.05\ df\ 5,80} = 2.33$

The results of the analysis of variance using the Fitness Indices yields nonsignificant F values for the order of presentation and treatment effects. There is a significant F value for the day effect.

The Duncan's Multiple Range Test (24: 131) presented in Table 111 was used to test for significant differences between the day Fitness Index means.

TABLE 111

DUNCAN'S MULTIPLE RANGE TEST

ON DAY FITNESS INDEX MEANS*

	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	SHORTEST SIGNIFICANT RANGE
MEANS	70.45	71.47	72.35	72.41	73.97	78.28	
70.45					3.52	7.83	3.76
71.47						6.81	3.96
72.35						5.93	4.08
72.41						5.78	4.17
73.97						4.31	4.25

* Any means underscored by the same line are not significantly different.

The Duncan's Multiple Range Test reveals that the means of the day Fitness Indices do not differ significantly for the first five days. The mean Fitness Index for the sixth test day does differ significantly from the mean Fitness Indices of the first five test days.

The means, standard deviations and ranges of Treatment F are presented in Table 1V.

TABLE 1V

TREATMENT F LEG TIMES AND NUMBER OF CHANGES

	MEAN	S.D.	RANGE
Left Leg Time	1:45	1:03	0 - 4:00
Right Leg Time	1:56	1:07	0 - 4:00
Number of Changes	2:11	1:53	0 - 5

Table 1V reveals that some subjects did not change their lead leg during the step test even when they had the opportunity to do so as often as they desired in Treatment F.

The correlations between the Fitness Indices for each test day are presented in Table V.

TABLE V

TEST DAY FITNESS INDEX CORRELATIONS

DAY	1	2	3	4	5	6
1	*					
2	.87	*				
3	.94	.93	*			
4	.89	.96	.95	*		
5	.88	.92	.97	.96	*	
6	.91	.92	.93	.95	.91	*

$r_{.05\ df\ 17} = .456$

Table V reveals high positive significant correlations between the fitness indices for each of the six test days.

The correlations between the Fitness Indices for each treatment are presented in Table Vl.

TABLE Vl

TREATMENT FITNESS INDEX CORRELATIONS

TREATMENT	A	B	C	D	E	F
A	*					
B	.87	*				
C	.94	.87	*			
D	.93	.92	.91	*		
E	.91	.92	.82	.94	*	
F	.81	.80	.87	.82	.79	*

$r_{.05\ df\ 17} = .456$

The correlations realized in Table Vl would indicate high positive significant correlations between the fitness indices for each of the six different Step Test treatments.

Endurance Tests

The analysis of the Endurance Test data is presented in the following order: means, standard deviations and ranges of each variable; the correlations between Endurance test variables; and endurance correlation between legs.

The means, standard deviations and ranges of the Endurance test variables are presented in Table Vll.

TABLE Vll

ENDURANCE TEST MEANS, STANDARD DEVIATIONS AND RANGES

VARIABLE	MEAN	S.D.	RANGE	
Body Weight(L)	155.22	15.51	129.00 -	177.00
Body Weight(R)	155.33	15.73	129.00 -	178.00
Standing Height	68.86	2.31	65.00 -	73.00

TABLE V11 continued....

VARIABLE	MEAN	S.D.	RANGE
Length of Upper Leg(L)	17.63	1.03	16.00 - 19.25
Length of Upper Leg(R)	17.90	1.10	16.25 - 19.75
Length of Lower Leg(L)	19.24	1.09	16.25 - 21.00
Length of Lower Leg(R)	19.47	1.05	17.75 - 20.75
Total Leg Length(L)	36.86	1.93	34.00 - 40.25
Total Leg Length(R)	37.35	2.01	34.00 - 41.25
Height of Bench(L)	16.78	0.81	16.00 - 18.00
Height of Bench(R)	16.83	0.86	16.00 - 18.00
Resting Heart Rate(L)	79.44	18.46	55.00 - 107.00
Resting Heart Rate(R)	68.06	10.32	55.00 - 87.00
Exercise Heart Rate(L)	178.06	21.13	141.00 - 214.00
Exercise Heart Rate(R)	180.44	16.18	150.00 - 214.00
Work(L)	73,698.38	48,337.60	25,684.17 - 186,480.00
Work(R)	75,691.44	50,246.75	29,640.00 - 196,615.96

The 't-test' of the skewness of the endurance scores did not yield any significant values.

The correlations between the Endurance test variables are presented in Table V111.

TABLE V111

ENDURANCE TEST VARIABLE CORRELATIONS

VARIABLE	COEFFICIENTS OF CORRELATION 1	2	3	4	5	6	7	8	9	10
1. Weight	*									
2. Height	.62	*								
3. L. ULL*	.52	.65	*							
4. R. ULL	.54	.74	.80	*						
5. L. LLL	.41	.91	.67	.76	*					
6. R. LLL	.50	.95	.68	.70	.95	*				
7. L. TLL	.51	.86	.91	.85	.92	.89	*			
8. R. TLL	.54	.92	.80	.92	.93	.92	.95	*		
9. L. Work	-.12	-.19	-.28	-.19	-.03	-.16	-.17	-.11	*	
10. R. Work	-.14	-.30	-.39	-.32	-.21	-.24	-.32	-.29	.91	*

*L = Left, R = Right, ULL = Upper Leg Length, LLL = Lower Leg Length TLL = Total Leg Length

Table V111 reveals positive significant correlations between the anthropometric variables. The correlations between the anthropometric variables and endurance measures are negative and non-significant. There is a high positive significant correlation between left and right leg endurance.

The correlations between left and right legs for the Endurance test are presented in Table 1X. Table 1X also includes the correlations between legs when the subject has indicated a dominant leg.

TABLE 1X

ENDURANCE CORRELATIONS BETWEEN LEGS

SAMPLE	COEFFICIENT OF CORRELATION
Total	.91*
Left Leg Dominant	.86*
Right Leg Dominant	.97*

* Significant at .05 level

Table 1X indicates significant correlations were found for between leg endurance measures for the total sample and the left and right leg dominant groups.

Strength Tests

The analysis of the Strength test data is presented in the following order: reliability coefficients; means, standard deviations and ranges of variables; the correlations between legs.

The reliability coefficients presented in Table X were determined from the correlation matrix of Strength test scores.

TABLE X

STRENGTH TEST RELIABILITY COEFFICIENTS

TEST	RELIABILITY COEFFICIENT		
Left Leg	.82*	.81**	.86***
Right Leg	.90*	.81**	.94***

* Test-Retest - test 1 and 2

** Test-Retest - test 1 and 3

*** Test-Retest - test 2 and 3

The coefficients presented in Table X indicate a high degree of reliability can be associated with the Strength test employed.

The means, standard deviations and ranges of strength test variables are presented in Table Xl.

TABLE Xl

STRENGTH TEST MEANS, STANDARD DEVIATIONS AND RANGES

VARIABLE	MEAN	S.D.	RANGE
Body Weight	156.50	15.74	130.00 - 179.00
Resting Heart Rate	77	16.32	55.00 - 110.00
Exercise Heart Rate	143	18.78	113.00 - 173.00
Test 1 (Left)	427.22	103.11	250.00 - 667.00
Test 1 (Right)	406.39	91.85	239.00 - 547.00
Test 2 (Left)	429.72	97.46	232.00 - 637.00
Test 2 (Right)	436.50	122.13	227.00 - 735.00
Test 3 (Left)	448.17	106.44	194.00 - 639.00
Test 3 (Right)	433.78	113.44	233.00 - 715.00
Mean Strength(Left)	435.04	96.36	225.00 - 597.00
Mean Strength(Right)	425.54	105.11	233.00 - 645.00
Strength/Body Weight(Left)	2.80	0.60	1.46 - 3.52
Strength/Body Weight(Right)	2.71	0.56	1.51 - 3.71

The "t-test" of the skewness of the strength scores did not yield any significant values.

The correlations between legs for the strength measure and strength per unit body weight are presented in Table X11.

TABLE X11

STRENGTH CORRELATIONS BETWEEN LEGS

VARIABLE	SAMPLE	COEFFICIENT OF CORRELATION
	Total	.90
Strength	Left Leg Dominant	.87
	Right Leg Dominant	.94
	Total	.86
Strength/Weight	Left Leg Dominant	.82
	Right Leg Dominant	.92

Table X11 indicates significant correlations were found for between leg strength measures for the total sample and the left and right leg dominant group.

Inter Test Relationships

The relationships between the Step, Endurance, and Strength test and the anthropometric variables are presented in Table X111.

Table X111 reveals nonsignificant correlations between the anthropometric measures and the Endurance, Strength and Step tests with the one exception of body weight and right leg strength which is positive and significant.

TABLE X111

TEST CORRELATIONS WITH ANTHROPOMETRIC VARIABLES

	WEIGHT	HEIGHT	L.* ULL	R. ULL	L. LLL	R. LLL	L. TLL	R. TLL
Left Work	-.12	-.19	-.28	-.12	-.03	-.12	-.17	-.11
Right Work	-.14	-.30	-.39	-.32	-.21	-.24	-.32	-.29
Left Strength/Weight	-.23	-.15	-.10	-.22	-.14	-.06	-.13	-.14
Right Strength/Weight	-.05	-.04	-.17	-.29	-.12	-.02	-.16	-.14
Left Strength	.28	.18	.16	.05	.08	.21	.13	.14
Right Strength	.50	.24	.08	.01	.07	.24	.08	.11
Treatment A	-.23	-.33	-.34	-.42	-.34	-.32	-.37	-.39
Treatment B	-.14	-.19	-.24	-.36	-.21	-.21	-.24	-.30
Treatment C	-.19	-.14	-.29	-.27	-.12	-.18	-.22	-.24
Treatment D	-.19	-.15	-.17	-.29	-.15	-.15	-.18	-.22
Treatment E	-.08	-.12	-.13	-.21	-.13	-.14	-.14	-.19
Treatment F	-.10	-.10	-.27	-.28	-.07	-.10	-.19	-.20

L = Left

R = Right

ULL = Upper Leg Length

LLL = Lower Leg Length

TLL = Total Leg Length

$r_{.05 \text{ df } 17} = .456$

The relationships between Endurance and Strength tests are presented in Table XlV. Relationships are included for the total sample, left leg dominant group and right leg dominant group.

TABLE XlV

ENDURANCE AND STRENGTH TEST CORRELATIONS

	LEFT ENDURANCE			RIGHT ENDURANCE		
	TOTAL SAMPLE	LEFT DOM.	RIGHT DOM.	TOTAL SAMPLE	LEFT DOM.	RIGHT DOM.
Left St/Wt	.36	.65	.14	.44	.66	.27
Right St/Wt	.28	.41	.14	.38	.45	.31
Left St	.32	.62	.00	.39	.58	.18
Right St	.18	.37	.03	.28	.36	.16

Total Sample $r_{.05\ df\ 17} = .456$

Left Leg Dominant $r_{.05\ df\ 9} = .602$

Right Leg Dominant $r_{.05\ df\ 7} = .666$

Table XlV indicates nonsignificant correlations between strength, strength/weight and the endurance measures for the total sample. There is a significant correlation between left leg strength/weight and left and right leg endurance when dominant leg groups are considered. Left leg strength and left leg endurance correlate significantly when only the left leg dominant group is considered.

The relationships between the Step, Endurance and Strength tests are presented in Table XV.

Table XV reveals positive significant correlations between the Step and Endurance tests.

TABLE XV

STEP, ENDURANCE AND STRENGTH TEST CORRELATIONS

	LEFT WORK	RIGHT WORK	LEFT ST/WT*	RIGHT ST/WT	LEFT ST	RIGHT ST
Treatment A	.60	.82	.23	.15	.14	.03
Treatment B	.43	.62	.08	.02	.02	.05
Treatment C	.59	.76	.21	.07	.13	.02
Treatment D	.52	.69	.09	.02	.02	.10
Treatment E	.59	.71	.14	.05	.12	.01
Treatment F	.69	.80	.26	.20	.22	.12

* ST = Strength WT = Weight

$r_{.05\ df\ 17} = .456$

The relationship between Step, Endurance and Strength tests when a dominant leg is considered is presented in Table XVl.

TABLE XVl

STEP, ENDURANCE AND STRENGTH TEST CORRELATIONS

DOMINANT LEG CONSIDERED

	LEFT LEG DOMINANT*			RIGHT LEG DOMINANT**		
	LEFT WORK	LEFT ST/WT	LEFT ST.	RIGHT WORK	RIGHT ST/WT	LEFT ST.
Treatment A	.39	.16	.16	.98	.26	.11
Treatment B	.14	.21	.07	.98	.27	.15
Treatment C	.35	.34	.00	.96	.39	.29
Treatment D	.26	.08	.03	.95	.20	.06
Treatment E	.46	.13	.18	.94	.24	.12
Treatment F	.38	.33	.13	.99	.38	.27

*Left Leg Dominant $r_{.05\ df\ 9} = .602$

**Right Leg Dominant $r_{.05\ df\ 7} = .666$

Table XVl indicates that when dominant leg groups are considered the only significant correlation is between the right leg Endurance test and the Step tests for the right leg dominant group.

The subjects choice of dominant leg and the dominant leg based on performance in the Endurance and Strength tests are presented in Table XVll.

TABLE XVll

DOMINANT LEG

SUBJECT	SUBJECTS INDICATION	ENDURANCE TEST	STRENGTH TEST
1	L*	R	R
2	L	R	R
3	L	L	R
4	R	L	L
5	L	L	L
6	L	R	R
7	R	L	L
8	R	R	L
9	R*	L	R
10	R	R	L
11	R	L	R
12	L	L	L
13	R	R	L
14	R	R	R
15	L	R	L
16	L	L	L
17	L	L	L
18	L	R	L

*Indicates that this leg was not used for the greatest time in treatment F.

Table XVll indicates the inability of individuals in the study to accurrately predict their dominant leg based on performance in the Endurance and Strength tests.

The mean resting, exercise and difference between resting and exercise heart rates for the endurance and strength tests are presented in Table XV111.

TABLE XV111

ENDURANCE AND STRENGTH TEST HEART RATES

	MEAN RESTING H.R.	MEAN EXERCISE H.R.	MEAN DIFFERENCE
Endurance Test	73.75	179.25	105.50
Strength Test	77.00	143.00	66.00
t-test Value	.64	5.80	6.99

$t_{.05\ df\ 34} = 2.03$

Table XV111 reveals that the mean resting heart rates for the endurance and strength tests did not differ significantly. However, the mean exercise heart rates and the mean differences between resting and exercise heart rates did differ significantly.

Discussion

Step Tests. The summary of the analysis of variance of the Fitness Indices presented in Table 11 indicate that the order of presentation, that is, the particular order in which each subject was tested in this study on the six treatments, did not have a significant effect on the Fitness Indices realized by the subjects. Table 11 indicates nonsignificant values were obtained for the treatment effect, that is, in the case of this study the six selected sequences of changing lead leg did not have a significant effect on the Fitness Indices. This nonsignificant treatment effect causes a failure to reject the

null hypothesis of the main problem of this study and indicates that when the lead leg is changed at selected intervals during the particular step test used in this study there is no difference in the Fitness Indices obtained by each subject. Significant differences in the Fitness Indices over the period of time for the six tests are indicated in Table 11. This significant day effect, or what may be termed a carry over or training effect in this study, indicates that the magnitude of the change in Fitness Indices of the subjects was great enough for there to be a significant difference between the first test day and the last test day. In this study, Table 111, indicates there was no significant difference in the Fitness Indices for the first five test days and that only the Fitness Indices realized by the subjects on the sixth test day do differ significantly from those of the other five test days. This difference may be due to an improvement in physiological efficiency or tolerance. The difference may also be attributed to several psychological factors as expressed by Day (21), which are associated with step test studies. The subjects familiarity with the test and the testing situation may result in improved scores. In this study it was important that each subject complete each treatment because of the different sequences of changing lead leg and this may have caused some anxiety because of an individuals concern as to whether or not he could complete the particular treatment he was being tested on. The subjects after having completed five test sessions may have had little anxiety or concern about being able to complete the final test treatment. Since the Step Test used was fairly

severe for some individuals, the fact that the sixth test day was the last day of Step Test treatments may have resulted in the improved performance since the subjects knew they would not have to do the test again.

During Treatment F the subjects were allowed to change lead leg as often as they desired. The subjects were asked to indicate which leg they felt was their dominant leg and to use that leg as their lead leg to start the test treatment. Table lV indicates the mean time each leg was used as a lead leg and the mean number of changes in Treatment F. It can be seen that some subjects did not change lead leg during Treatment F, which would indicate that these subjects thought they could achieve best results without any sequence of changes for lead leg. The number of changes did not correlate significantly (.30) with the Fitness Indices realized by the subjects in Treatment F, that is in this study as the number of changes increased to as many as five in Treatment F the Fitness Indices did not correlate significantly. It is noted that even in the case when the subjects had their choice as to number of changes they did not change lead leg as often as they did in Treatment C (changing lead leg every 30 seconds equals seven changes). When the subjects were asked to indicate which leg they thought was their dominant leg some were not certain which leg was the dominant leg or if in fact they would consider one leg dominant over the other. Two subjects indicated their left leg dominant because of injuries one year prior to the testing which they though may have weakened their right leg. Table XVll reveals that two subjects did not

use the leg they indicated as their dominant leg for the longest period of time in Treatment F. It can also be seen from Table XV11 that only in the case of five subjects was the leg indicated dominant in Treatment F the same leg that was dominant in performance during both the Endurance and Strength tests. This uncertainty as to dominant leg would imply that some reservation must be made in conclusions concerning comparisons of the dominant leg groups with the total sample.

The correlations presented in Table V between each test day, what may be termed test-retest reliability in this case agree with those of Karpovich (42). The correlations ranging from .87 to .97 lend further support to the argument that Step tests have high test-retest reliability.

The analysis of variance presented in Table 11 is further supported by Table V1 which reveals positive significant correlations between each of the Step test treatments. Correlations of this order would again indicate that there is no significant difference between the Step test treatments.

Endurance Test. The Endurance test variable correlations presented in Table V111 reveal positive significant correlations between weight, height, lower leg length, upper leg length and total leg length with one exception, the correlation between left lower leg length and body weight which is approaching significance. Negative nonsignificant correlations were found between the total work done and weight, height, and the components of leg length. In this study these negative correlations would indicate that as an individual increases in these anthropometric

measures there is a decrease in the total amount of work done. It must be noted that for the Endurance test the knee angle was set to 90 degrees for each individual and this was done by increasing or decreasing the height of the bench. Table 1X indicates there is a high positive significant correlation (.91) between the left and right leg endurance. The correlation when the left leg dominant group is considered is .86 and when the right leg dominant is considered is .97. This could imply that of the subjects in this study, those who indicate right leg dominance that their left leg also has more endurance than the right leg of those subjects who indicate their left leg is dominant.

Strength Test. The reliability coefficients presented in Table X indicate that the test-retest reliability coefficient between the three strength tests used to determine strength and strength per unit body weight were of similar nature. Table X1 reveals a high positive significant correlation between left and right leg strength and strength per unit body weight. This would indicate little difference between the two legs on the strength test employed in the study. When the left and right leg dominant groups are considered the results are similar to the findings for the Endurance test, that is, in those subjects who indicate their right leg is dominant their left leg also has more strength than the right leg of those subjects who indicate their left leg is dominant. It is noted that the starting angle for the strength test was 135 degrees and that during the muscle contraction due to joint compression the angle reached a maximum of approximately 150 degrees. This would yield maximum strength scores in

agreement with the findings of Danielson (20), Linford (46), and Linford and Rarich (47).

Inter Test Relationships. Table X111 discloses non-significant correlations between the anthropometric measures included in the study and the Step, Endurance and Strength tests. The nature of the correlations with the Step test, the Endurance test and the Strength per unit body weight were negative. The result being that those subjects of greater stature did not achieve fitness indices as high as those subjects of small stature in this study. Similar results are noted for the Endurance test. In the Strength test the strength per unit body weight does not increase in proportion to the increases in anthropometric measures. The nature of the correlation between strength and the anthropometric measures was positive. There was one significant correlation coefficient that being between body weight and right leg strength, indicating an increase in right leg strength among the subjects used in this study as body weight is increased. These findings agree with the work of Bookwalter (8), Hardy _et al_ (35), Keen and Sloan (45), and Seltzer (56).

The relationships between the Endurance and Strength tests presented in Table X1V reveal coefficients that are positive and are approaching significance between the two tests, but no values are significant when the total sample is considered. Significant correlations were found between left and right leg endurance and left leg strength per unit body weight and strength for the left leg dominant group. This can be expected since in the strength test those subjects with left leg dominant

(Table Xll) did not have as high inter leg correlations as the right leg dominant group and thus the increase in left leg strength is not accompanied by a similar increase in right leg strength. These relationships agree with the work of Elbel (25) who found significant correlations (.35, .26, .32) between leg strength and endurance.

The correlations between the Step, Endurance and Strength tests presented in Table Xll reveal positive significant correlations between left and right leg endurance and each of the six Step test treatments. The nature of these correlations indicates the role of endurance in the performance of a step test. This results in the rejection of the null hypothesis for the subsidiary problem concerning leg endurance and step test performance and implies that there is a significant relationship between leg endurance and step test performance. The correlations between strength per unit body weight and strength and the six Step test treatments were positive but non significant. This results in acceptance of the null hypothesis for the subsidiary problem concerning leg strength and step test performance and implies there is no relationship between leg strength and step test performance. These findings are similar to those of Cureton (19), who found insignificant correlations between strength per unit body weight and cardiovascular tests. The nature of the correlations in XVl where dominant leg is considered indicate that those subjects who indicate their right leg is dominant did have highly significant correlations between right leg endurance and step test performance. This implies that those subjects

who did select their right leg as dominant were correct as this leg was also dominant in the Endurance test and Table XV indicated significant correlations between endurance and step test performance.

The values presented in Table XV11l result in rejection of the null hypothesis of the subsidiary problem concerning the difference in heart rate change during maximal strength and endurance tests and would indicate there is a significant difference in the changes in heart rate during these two tests. The changes reported in this study contradict the work of de Vries (22), and Morehouse and Miller (51) who report only slight increases in heart rate during maximal static exercises. Heart rate changes of the order found in this study agree with the findings of Shavartz (59), who after studying isotonic and isometric exercises concluded, increasing the load in isometric contraction results in proportional increases in heart rate. He also found two fold increases above resting heart rate when maximum isometric tension was developed which is similar to the changes of this study. The changes in heart rate found in this study indicate that a training effect may be elicited by relatively short bouts of isometric exercise. The work of Hollman and Venrath (37), Karvonen, Kentala and Mustala (44), Durnin, Brockway and Whitcher (23), Roskamm (54) and Faria (29) indicates that increases of 60-70 percent over resting or terminal exercise heart rates of 140-150 beats per minute are sufficient to elicit a training effect. Although the Strength test heart rate changes were significantly different from the Endurance test heart rate changes Table XV11l reveals

the rates during the strength test comply with the changes necessary to elicit a training effect, that is, increases of approximately 85 percent over resting rates as well as being in the 140-150 beats per minute range.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to investigate the effect of changing lead leg (the leg which is placed on the bench first) on step test performance as indicated by changes in the fitness index. Subsidiary problems were:

1. To measure leg extensor strength from a standing position similar to that of stepping up onto the bench and its relation to step test performance.

2. To measure leg extensor endurance from positions similar to that of stepping up onto the bench and its relation to step test performance.

3. To measure changes in heart rate during maximal strength and endurance tests of the leg extensors.

Eighteen males enrolled at the University of Alberta in the freshmen Physical Education program volunteered as subjects for the study. Three subjects were randomly assigned to each different order of presentation for the step test treatments. During the Endurance and Strength tests the subjects were randomly assigned to tests for the left and right legs on the first day. Each subject completed six different step test treatments, two endurance tests and six trials on the two strength tests.

The analysis of variance using the Fitness Indices

from the Step test treatments did not yield significant F values for the order of presentation effect or the treatment effect. A significant F value was realized for the day effect.

The correlation matrix computed did yield significant r values for:

1. The Fitness Indices for each test day.

2. The Fitness Indices for each treatment.

3. The anthropometric variables measured in the Endurance test.

4. Left and right leg endurance.

5. Left and right leg strength per unit body weight and strength.

6. Left leg and right leg endurance and each of the Step test treatments.

The 't-test' of the mean heart rate changes during the Endurance and Strength test did yield significant values for the differences in maximum heart rate and mean difference between resting and maximum heart rate for the two tests.

The 't-test' of the skewness, that is, deviation from normality, of the variables measured in the study did not yield any significant values.

Conclusions

On the basis of test results and statistical analysis the following conclusions are justifiable for this study:

1. Changing lead leg does not effect step test performance as indicated by changes in the fitness index.

2. Leg extensor strength does not significantly effect step test performance.

3. Leg extensor endurance does significantly effect step test performance.

4. The changes in heart rate during maximal strength and endurance tests are significantly different, however both tests result in heart rate changes great enough to elicit a training effect.

Recommendations

The following recommendations are made following the study:

1. Step test studies in which the individuals do not know which test day will be the final testing session, in order to alleviate the psychological factors related to the final test session.

2. Step test studies involving a more severe step test, that is, increased time or bench height. Including in this new study sequences of changing lead leg similar to the ones used in this study with the scoring done such that an individual does not have to complete a certain time period.

3. A study testing several methods of determining a dominant leg.

4. A study using an endurance test similar to the one employed in this study, except that all individuals use the same height of bench regardless of stature.

5. Studies to evaluate the training effect elicited

by isotonic and isometric exercises which result in similar heart rate changes during the exercise.

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APPENDIX A

TREATMENT PRESENTATION

RANDOMIZED LATIN SQUARE TREATMENT PRESENTATION

ORDER OF PRESENTATION	SUBJECT	DAYS 1	2	3	4	5	6
1	1 2 3	A	B	C	D	E	F
2	4 5 6	B	C	F	A	D	E
3	7 8 9	C	F	B	E	A	D
4	10 11 12	D	E	A	B	F	C
5	13 14 15	E	A	D	F	C	B
6	16 17 18	F	D	E	C	B	A

Treatment A - Subject uses only left leg as lead leg.

Treatment B - Subject changes lead leg after two minutes.

Treatment C - Subject changes lead leg every thirty seconds.

Treatment D - Subject uses only right leg as lead leg.

Treatment E - Subject changes lead leg every minute.

Treatment F - Subjects own choice of lead leg.

APPENDIX B

DATA COLLECTION SHEET

THESIS TESTING - DATA SHEET

SUBJECT_______________ORDER OF PRESENTATION_____

AGE_____

PHASE 1 - STEP TEST TREATMENTS

DAY 1 TREATMENT_____ HEART RATE_____ INDEX = $\frac{240 \times 100}{5.5 \times H.R.}$ = _____

DAY 2 TREATMENT_____ HEART RATE_____ INDEX = $\frac{240 \times 100}{5.5 \times}$ = _____

DAY 3 TREATMENT_____ HEART RATE_____ INDEX = $\frac{240 \times 100}{5.5 \times}$ = _____

DAY 4 TREATMENT_____ HEART RATE_____ INDEX = $\frac{240 \times 100}{5.5 \times}$ = _____

DAY 5 TREATMENT_____ HEART RATE_____ INDEX = $\frac{240 \times 100}{5.5 \times}$ = _____

DAY 6 TREATMENT_____ HEART RATE_____ INDEX = $\frac{240 \times 100}{5.5 \times}$ = _____

TREATMENT "F" record time right leg is used and number of changes.

THESIS TESTING - DATA SHEET

SUBJECT________________ORDER OF PRESENTATION_____

AGE_____

PHASE 11 ENDURANCE MEASURE	LEFT LEG	RIGHT LEG	
1. Body Weight	________	________	lbs.
2. Standing Height	________	________	in.
3. Length of Upper Leg	________	________	in.
4. Length of Lower Leg	________	________	in.
5. Total Leg Length	________	________	in.
6. Height of Bench	________	________	in.
7. Resting Heart Rate	________	________	bts/min.
8. Exercise Heart Rate	________	________	bts/min.
9. Length of Exercise	________	________	secs.
10. Number of Repetitions	________	________	
11. Work = $\frac{\text{Reps x Upper Leg Lgth x B.W.}}{12}$	________	________	ft. lbs.

PHASE 111 STRENGTH MEASURES	LEFT LEG	RIGHT LEG	
1. Body Weight	________	________	lbs.
2. Resting Heart Rate	________	________	bts/min.
3. Test 1	________	________	lbs.
4. Test 2	________	________	lbs.
5. Test 3	________	________	lbs.
6. Average Strength	________	________	lbs.
7. Strength/Unit Body Weight	________	________	lbs/lb.
8. Exercise Heart Rate	________	________	bts/min.

APPENDIX C

TREATMENT SUMS

FITNESS INDICES TREATMENT SUMS

DAYS	TREATMENTS A	B	C	D	E	F
1	195.34	200.44	190.91	185.16	196.28	199.85
2	208.15	198.51	199.56	209.43	220.11	204.52
3	194.88	195.49	200.58	196.98	192.85	190.90
4	241.03	243.70	279.03	228.39	227.05	250.84
5	214.59	237.88	219.03	218.08	216.28	213.53
6	275.21	261.07	260.10	253.95	252.31	229.04
SUMS	1329.20	1337.09	1349.21	1291.99	1304.88	1288.68

APPENDIX D

DAY SUMS

FITNESS INDICES

ORDER OF PRESENTATION	SUBJECT	DAYS					
		1	2	3	4	5	6
1	1	73.96	67.18	68.18	67.13	66.12	70.38
	2	55.26	65.13	54.42	57.42	59.78	62.34
	3	66.12	68.18	68.18	60.61	70.38	67.13
2	4	57.42	57.42	59.78	61.46	61.46	64.17
	5	73.96	73.96	76.56	72.73	72.73	85.56
	6	67.13	68.18	68.18	73.96	75.24	70.38
3	7	59.78	60.61	59.78	58.97	61.46	59.78
	8	69.26	64.17	64.17	62.34	58.18	63.24
	9	71.54	66.12	71.54	71.54	75.24	73.96
4	10	90.91	87.27	106.43	99.17	114.83	111.89
	11	56.67	58.97	55.26	58.97	56.67	63.24
	12	80.81	80.81	79.34	85.56	79.34	103.90
5	13	61.46	65.13	63.24	62.34	61.46	60.61
	14	69.26	71.54	69.26	70.38	75.24	68.18
	15	85.56	77.92	85.56	80.81	82.33	109.09
6	16	64.17	68.18	69.26	62.34	67.13	66.12
	17	73.96	79.34	73.96	76.55	72.73	72.73
	18	90.91	106.43	109.09	121.21	121.21	136.36
DAY SUMS		1268.14	1286.49	1302.34	1303.49	1331.53	1409.06